Contemporary Topics in ECE 55:195, Spring 2005
Introduction to Wireless Sensor Networks
Midterm Exam Solutions, 10 March 2005

List and briefly explain the purpose of four building blocks of a "mote".

> A "mote" is a node in a WSN, and it has several components. The MCU/CPU is the "brains" or controller that coordinates the operation of the mote. The transmitter/receiver unit (i.e., transceiver) provides communication. The sensors and interfaces (e.g., A/D converter) and actuators interface with the physical world. An operating system (OS) such as TinyOS provides software services and isolates the programmer from the hardware.

Name and explain two differences and two similarities between the concept of a WSN and traditional telemetry.

> Telemetry and WSNs both use wireless communication to control and measure. Radio is most often used for communication in both. WSNs are inherently networked, while telemetry is mostly stand-alone, non-networked node(s) that send data back to a base station. Nodes in a WSN are inexpensive compared to telemetry nodes, but there may be many (hundreds) deployed in a WSN while in telemetry only a few may be deployed.

A 500 m, 900 MHz link has two antennas that are 1 m above the ground. Do we have RF LOS? "Yes" of "No" will not suffice; motivate your answer with a diagram or computations or both.

> The wavelength at 900 MHz is 0.333 m. Substitute this and $D_1 = D_2 =$ 250 m and $n = 1$ into the supplied equation to find the first Fresnel zone height $F_1 = 6.45$ m, and 60% of this (the 60% rule) is 3.87 m. The antennas are only 1 m above ground, so we don't have RF LOS.

How is RSSI used in WSNs?

> Received Signal Strength Indicatior (RSSI) can be used as a link quality indicator in WSNs. It can be used estimate bit error rates, and to construct WSN node links. For example, one can program mote to communicate with other motes only if the RSSI between them is above a certain threshold. It can be used as a rough measure of the distance between motes.

A manufacturer claims its radio can make reliable reception if the received power is -95 dBm. How many Watt is this?

> The "dBm" implies the reference power is 1 mW or 1×10^{-3} W. The receiver power is a factor $1\times10^{(95/10)}$ times smaller than 1 mW, or $1\times10^{-3}/1\times10^{(-95/10)} = 10^{(-95/10)} = 10^{-12.5} = 3.16\times10^{-13}$ W.

Estimate the path loss in dB at 900 MHz in an ***indoor*** environment. There are *2* floors are 2 walls between transmitter and receiver. Use the table on the last page and make reasonable assumption s about losses and distances.

> Assume the distance between walls is 4 m (~ 12 feet) and the distance between floor and ceiling is 2.5 m (~8 feet). This makes the distance between transmitter and receiver about 8 m. From the table, at 900 MHz, $n = 3$ for an indoor office environment. Assume the unit loss 20 dB, then $Path\ Loss = 20 + 10 \times 3 log(8) =$ 47 dB.

Explain why, with respect to WSN MACs, effective collision avoidance is more important than fairness.

> Power consumption is of paramount in WSNs. Collisions waste power—first on the original collision and then the packet must be resent again. Rather than requiring that each node get fair access to the medium, in WSNs a holistic view is more appropriate. That is, it often makes more sense for an individual node not to have access to the medium as long as the message eventually gets sent, possibly by another node. This works because in WSN there are built-in redundancies in the form of multiple nodes that sense the same or very similar variables.

One major issue in TDMA MAC protocols that of *limited scaling*. Explain this statement in a 4-6 sentence paragraph.

> In TDMA a frame consisting of a fixed number of time slots n that all nodes in the network agree upon. Each node is assigned a time slot. It has control of the medium during its time slot. When the number of actual nodes m in the network is less than or equal to than the available slots n, new nodes can easily join the network—they simply grab/gets assigned an unused slot. However, to add nodes when $m > n$ require the definition of a new TDMA frame, node reprogramming, node reassignment, and possibly re-establishing links between nodes in the network. That is, TDMA does not scale beyond its initial n slots.

Describe the LEACH MAC protocol.

> See lecture notes and textbook.

Explain the difference between non-persistent and 1-persistent CSMA

> In non-persistent CSMA, a node wakes up, and when it find the medium busy, it goes back to sleep for a random amount of time, wakes up, and tries to communicate then. In persistent CSMA, the node stays awake until the medium becomes free.

What is the hidden-terminal problem as it relates to CSMA in WSNs? Use a figure to explain.

See lecture notes.

Explain the advantage of adding the message duration to *each packet* in S-MAC.

Other nodes know exactly how long the transmission is going to last and can sleep until the media becomes free. This saves power.

List an briefly explain four advantages of spread spectrum communication.

SS communication is secure because an eavesdropper must know either the spreading codes (DSS) or hopping sequence (FHS) to intercept the communication. SS utilizes the bandwidth better than tradition communication schemes because guard band between channels are not needed. SS has better noise immunity, because narrowband noise impact only a small fraction of the total SS signal. Finally, multipath effects are greatly reduced in SS because multiple wavelength are used to transmit information—at one frequency destructive interference may occur, but this is compensated for by constructive interference at an adjacent frequency.

The output from a CDMA receiver is "1 1 1 2" which contains messages from two transmitters. The spreading codes are:

C1 = 1	**1**
C2 = 1	**-1**

Decode the two messages

Receiver 1, bit A: (1 1)•(1 1) = +2, which is equivalent to 1

Receiver 1, bit B: (1 2)•(1 1) = +3, which is equivalent to 1

Thus, transmitter 1 sent "1 1"

Receiver 2, bit A: (1 1)•(1 -1) = 0, which is equivalent to 0

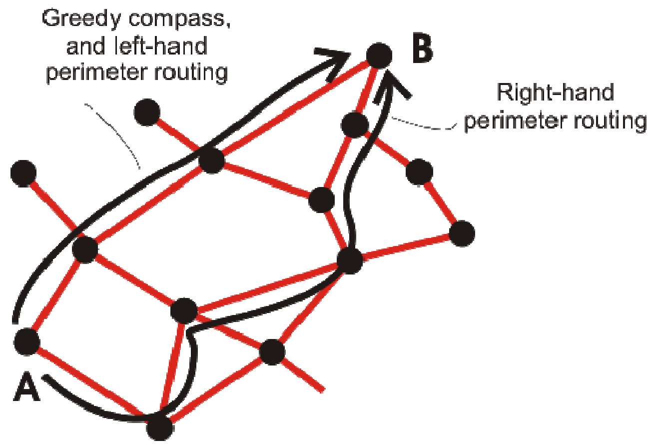
Receiver 2, bit B: (1 2)•(1 -1) = -1, which is equivalent to 0

Thus, transmitter 2 sent "0 0"

We assumed output > 1 => "1", otherwise "0"

Below is a connectivity graph for a WSN. Start at node A, and route the packets to node B using (a) the greedy compass routing and (b) the convex perimeter routing.

Possibilities are indicated on the figure.



For the following questions write "True" or "False".

In free space RF power loss ~$1/R^2$ but when the transmitter and receiver is close to the ground, the loss can be ~$1/R^{4}$. (True)

Visual LOS does not imply RF LOS. (True)

With respect to WSN MACs, fairness is more important than collision avoidance. (False)

Power considerations make channel utilization a crucial, if not the most important attribute of a WSN MAC. (False)

Energy waste from collisions is more in contention MAC protocols than in scheduled MAC protocols. (True)

CSMA is an example of a contention-based MAC protocol. (True)

A major problem with "Routing on a Curve" is that each node must know the location of all nodes along the routing path. (False)

CDMA can be seen as an example of what is known a direct sequence spread spectrum? (True)

A major disadvantage of perimeter routing in WSN is that path construction requires knowledge of the global topology. (False)

When routing a packet in a WSN, more hops increase delay, but the advantage is that it increases energy efficiency for the WSN as a whole. (True)